STORED-TOBACCO INSECTS

Biology and Control

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CONTENTS

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Biology and Control[1]

Prepared by the Stored-Product Insects Branch, Market Quality Research Division, Agricultural Marketing Service

INTRODUCTION

One of the oldest and largest industries in the United States comprises the curing, storing, processing, and manufacturing of tobacco. Most tobaccos are held in storage for 2 years or more for natural aging. During this time the cigarette beetle (*Lasioderma serricorne* (F.)) and the tobacco moth (*Ephestia elutella* (Hbn.)) cause heavy losses. The cigarette beetle is also a pest of tobacco products.

In this country most of the tobacco held for aging is stored near the manufacturing centers. Storage of cigarette-type tobacco is concentrated largely in North Carolina and Virginia; much of this tobacco for export is stored near Norfolk, Va., and at Morehead City and Wilmington, N.C. Large quantities of cigar tobacco are stored in New York, Pennsylvania, Connecticut, and Florida.

Manufacturers prefer to maintain large stocks of tobacco at all times. Total stocks of tobacco on hand in the United States and Puerto Rico in October 1960 were estimated at about 4½ billion pounds farm sales weight. Tobacco dealers and manufacturers take many precautions to eliminate insects from their warehouses and factories and make a constant effort to keep their stocks free from insect infestation.

Insect damage to stored tobacco and to tobacco products was estimated in 1941 to be more than $11 million. About 1950, it was believed to be between $5 and $10 million. Since 1950, new and improved preventive and control measures have been developed. However, stocks of tobacco have increased, and the value of these stocks has increased greatly. It is difficult to estimate the amount of insect damage, but annual losses from insects probably are more than $10 million. Much of these losses could be prevented by more energetic application of the measures discussed in this bulletin.

Losses to cured tobacco caused by insects are of five kinds: (a) Loss in quantity and quality of leaf tobacco; (b) loss in value of manufactured tobacco, such as the cigarettes and cigars that become infested at the factory or in wholesale or retail establishments; (c) loss on exported tobaccos due to refusal of customers to accept infested tobacco, at least unless discounts are granted; (d) discrimina-

[1] This publication supersedes U.S. Department of Agriculture Circular No. 869, Control of Insects in Stored and Manufactured Tobacco, by Joseph N. Tenhet and C. O. Bare.

tion in other countries against infested American tobaccos; and (e) loss of good will, as when a customer turns away from a particular brand after buying an infested product.

Tobacco production in other countries had greatly increased by 1962. This tobacco competes with American tobacco for the foreign market. Because American tobacco is higher priced and of premium quality, foreign customers are highly critical of insect damage. This attitude of foreign buyers has made the American exporters more alert to insect damage. Moreover, in order to ship tobacco to some countries, the exporter must certify that the product is free from infestation by the tobacco moth, or show certification of fumigation. Inspection or fumigation at port is expensive.

The loss of good will to a manufacturer when a purchaser buys insect-infested merchandise is an intangible thing and difficult to evaluate. It can seriously hurt a dealer's business before he is aware of it, and the very thought of this kind of loss seriously disturbs any tobacco dealer or manufacturer.

This publication offers information on insect pests of stored and manufactured tobacco and the most modern, effective, and economical methods for the prevention and control of infestations.

THE CIGARETTE BEETLE

The cigarette beetle is cosmopolitan in distribution, having been carried over the world by commerce in tobacco and other materials. Specimens have been described from Tutankhamen's tomb in Egypt, which seems to indicate an African or Asiatic origin for the species. At least it was present in Egypt (*1*)[2] more than 3,500 years ago. It was recorded as a pest of cured tobacco in North Carolina as early as 1886 (*2*).

Description and Life History

The adult cigarette beetle is dark brown and less than 1/8 inch long. The head is drawn under the body when the beetle is at rest and usually when it is dead. The egg is pearly white, elongate-ovoid, and about 1/50 inch long. It is fragile, but has a waxy shell that is very resistant to drying. The larva, or grub, is tiny (almost microscopic) when first hatched, but it grows to a length of about 3/16 inch. It is creamy or grayish white and covered thickly with fine hairs, which appear to be light brown on mature larvae. When fully grown, the larva forms a thin cell or cocoon, in which it transforms into the inactive pupa, and from which the adult beetle emerges.

The adult beetle lives for 2 to 4 weeks—longer in cool weather—and each female lays from 40 to more than 100 eggs. The average number of eggs deposited, as determined by different scientists, has ranged from 40 to 76, but studies in North Carolina under warehouse conditions gave an average of 42. Most of the eggs were laid during the first 10 days after the adult emerged, but the largest numbers of eggs were laid on the fourth, fifth, and sixth days. About 80 percent of the eggs were deposited from the third to the ninth day and more than 90 percent after the second day (*9*). The egg hatches in 6 to 10 days, and the larva matures in about 30 to 50 days. In the summer in North Carolina and Virginia, the average incubation period is about 7 days, the larval stage 40 days, the pupal stage 5 days, the pre-emer-

[2] Italic numbers in parentheses refer to literature cited, page 38.

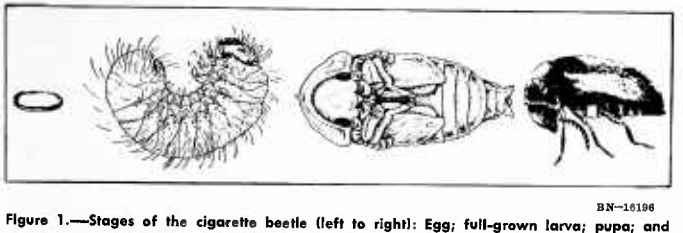

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Figure 1.—Stages of the cigarette beetle (left to right): Egg; full-grown larva; pupa; and adult. Greatly enlarged.

gence period 3 to 6 days, and the total life cycle about 56 days.[3] The four stages of this insect are shown in figure 1.

Seasonal Occurrence

The seasonal occurrence of the cigarette beetle varies with the conditions under which tobacco is stored and manufactured. In heated buildings or in the subtropical climate of Florida, there may be no well-defined hibernation period but a slowing of development during the winter. In Puerto Rico and throughout the tropics, the beetle is active during the entire year. Under such conditions all stages of the insect may be found at almost any time. In North Carolina and Virginia and farther north, the beetle passes the winter in the larval stage in tobacco or other hosts. The mortality of immature larvae is usually heavy and in severe winters the population of mature larvae may be materially reduced. If the tobacco temperature remains below 36° F. for 16 consecutive days, all larvae are killed (*7*), and such low temperatures occur frequently in Virginia. In brick warehouses and factories, however, infestations nearly always survive.

In the Richmond, Va., area the larvae begin to pupate late in the spring, and usually the first adults of the spring brood emerge late in May. Near Charleston, S.C., or Wilmington, N.C., emergence may start as early as the last week of March. The generations overlap, but peaks of emergence of different broods are rather sharply defined. At Richmond the spring peak is reached usually about the middle of June. Since most individuals of a generation complete development in 50 to 60 days, there are ordinarily two generations and part of a third generation each year in North Carolina and Virginia. This seasonal occurrence is shown in figure 2. At Richmond, there is usually a peak emergence in June, another in August, and a third in October. The third generation is usually smaller than the others, but in mild weather it may be large. A large number of the second-generation larvae and all of the third-generation larvae pass the winter in this stage.

The population of cigarette beetles fluctuates widely, but there is some indication of cycles of abundance. Beetles appear to be more abundant every other year, and perhaps there is a longer cycle, but the picture is somewhat obscured. In any storage warehouse the most important factors influencing population are temperature, relative humidity, and types, grades, age, and quantity of tobacco present. At times, parasitism may also be of some importance.

[3] In the insectary with the temperature constant at 80° F., and the relative humidity at 70 percent, the total life cycle is about 45 days.

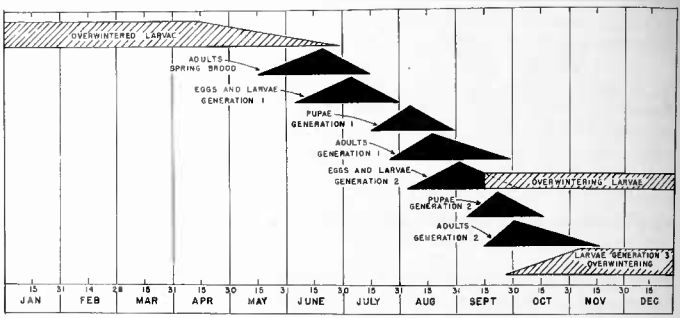

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Figure 2.—Seasonal occurrence of the cigarette beetle in Virginia and North Carolina.

Habits

Practically all injury to tobacco by the cigarette beetle is caused by the feeding of the larvae. The adults do not feed. The only damage they cause is by cutting exit holes to escape from the tobacco or package in which they pupated. Most of the adults attempt to leave the tobacco. However, these insects can mate and lay eggs in close confinement, and some of the adults do.

This insect attacks the principal types of cigarette, cigar, chewing, and snuff tobaccos, as well as most forms of manufactured tobacco. Burley and Maryland tobaccos are rarely attacked, however, and these types have never been known to be damaged economically.

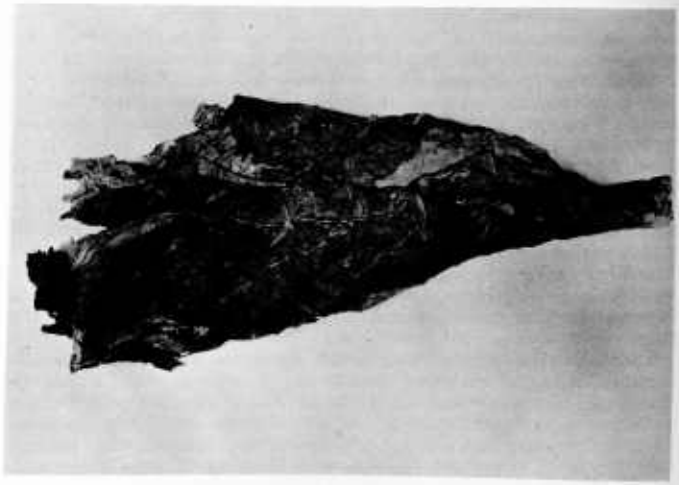

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Figure 3.—A hand or bundle of flue-cured tobacco, showing typical injury by the cigarette beetle. About one-third natural size.

The larva burrows through the tobacco, making rather clean-cut holes, and leaving behind a fine powder of excrement. Cigars and cigarettes are made unfit for smoking by the holes in the wrapper or paper, which prevent a satisfactory draught. Infested smoking or chewing tobacco or infested snuff is objectionable to the consumer from the aesthetic standpoint as well as in taste. However, the greatest losses caused by the cigarette beetle occur in leaf tobacco in storage. Injury to leaf tobacco is shown in figure 3.

The cigarette beetle has a very wide range of host foods; it is one of the most omnivorous of the storage pests. It has been recorded as infesting cottonseed meal, cottonseed, dry yeast, chili powder, curry powder, ginger, cayenne pepper, paprika, turmeric, saffron, nutmeg, mixed spices, licorice roots, pyrethrum powder, dried pyrethrum flowers, opium, belladonna, dates, raisins, dried figs, cereals, rice, bran, dried citrus pulp, leather, woolen cloth, bamboo, broomcorn, aniseed, areca nuts, copra, cassava, coffee beans, cacao beans, peanuts, dried vegetables, dried herbs, flax tow, dried Spanish moss (tow), dried insects, fish meal, meat meal, and other materials (*5* and *7*). It has been reported as damaging paper and also nylon cord used in the manufacture of automobile tires.

THE TOBACCO MOTH

The tobacco moth is widely distributed in the temperate and tropical climates of the world. It was first reported as a pest of American tobacco in 1930 (*3*), and now it is one of the important pests of flue-cured and oriental types of tobacco in the United States. It has never been recorded as attacking air-cured, fire-cured, or cigar types of tobacco. In 1937–40 an outbreak of this insect occurred in farmers' packhouses in North Carolina and Virginia. Farmers suffered heavy losses between the time their flue-cured tobacco was harvested and the time it was sold. Slight damage was reported from some farms in 1948 and 1949 and almost every year thereafter.

Description and Life History

The adult tobacco moth is a small gray or brownish-gray moth. It measures about ⅜ inch from head to tips of folded wings and has a wingspread of about ⅝ inch (*6*). The eggs are laid singly or in loose groups on or near tobacco. They are sandy white when laid, and gradually they turn darker. They are slightly elongate and about 1/45 inch long. The shell is very tough. The eggs are only loosely attached to the tobacco. The larva is tiny when first hatched, but it grows to ⅜ to ½ inch long. It is pinkish white and has a few fine hairs. The head is reddish brown, and the body has small brown spots along the back. When full grown the larva spins a weblike cocoon in which it transforms to a pupa. Adult moths emerge from the pupae.

Mating and egg laying usually begin within 24 hours after emergence. The average female probably lays more than 100 eggs, and as many as 279 have been recorded. The eggs hatch in 3 to 17 days, and the larvae reach maturity in 25 to 128 days. The pupal stage requires from 5 to 25 days. Under summer conditions the life cycle from egg to egg averages about 50 days—5 days for incubation, 35 days for larval development, and 10 days for pupation. The adult

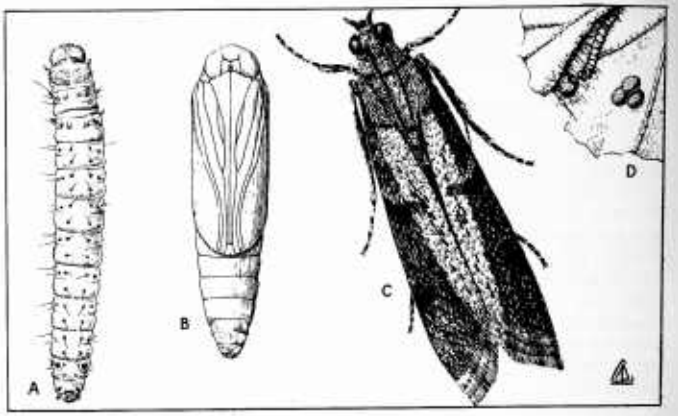

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Figure 4.—Stages of the tobacco moth: *A*, large larva; *B*, pupa; *C*, adult; and *D*, eggs and young larva on section of tobacco leaf. About seven times actual size.

moths may live as long as 7 or 8 days—longer in cool weather. The four stages of this insect are shown in figure 4.

Seasonal Occurrence

The tobacco moth passes the winter as a larva. In the fall most of the mature larvae leave the tobacco and migrate to cracks and crevices about the building, where they spin the loose cocoons of silk in which they hibernate. Some larvae may spin cocoons on or near the surface of the tobacco. Immature larvae may remain in the tobacco in an inactive state, and probably many of them fail to survive the winter. However, relatively few immature larvae enter the winter. Once hibernation has begun, the mature larvae seem able to withstand low temperatures for long periods. Larvae have been reported to survive the winter in unheated buildings in Canada at a temperature of −30° F. In North Carolina and Virginia, larvae have been known to survive exposure to near-zero temperatures for periods of 2 to 3 weeks.

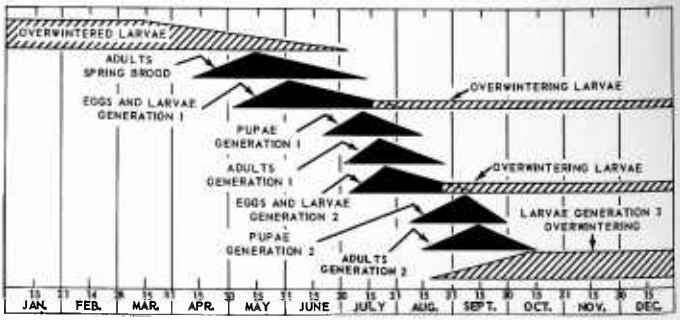

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Figure 5.—Seasonal occurrence of the tobacco moth in Virginia and North Carolina.

At Richmond, Va., pupation usually begins in April. Emergence of moths of the overwintered brood generally starts in May. At Charleston, S.C., and Wilmington, N.C., moths may emerge as early as the last week of March.

The peaks of emergence of the broods of the tobacco moth are a little more sharply defined than those of the cigarette beetle. In the Richmond area, emergence of the spring brood is usually at a peak in the last 2 weeks of May. The population of moths in a warehouse then declines, reaching a very low ebb early in July. A second peak of emergence occurs in August, and a third and usually much smaller peak is often noted late in September or in October (fig. 5). In 1948 and 1949 a full third brood occurred, and at Norfolk, Va., active moths were noted as late as the middle of December.

Habits

Only the larva of the tobacco moth feeds on tobacco. This insect does not attack manufactured tobacco products. It feeds only on leaf tobacco of the flue-cured and Turkish types, preferably of the better grades—those high in sugar and low in nicotine. Tobacco with a sugar content (dextrose before inversion) of more than 10 percent (much flue-cured tobacco contains 20 percent or more of sugar) and a nicotine content of less than 2 percent seems particularly attractive to the tobacco moth.

This insect is a heavier feeder than the cigarette beetle; in a severe infestation it devours many leaves completely except for the midrib and larger veins (fig. 6). In crawling, the larva leaves behind a

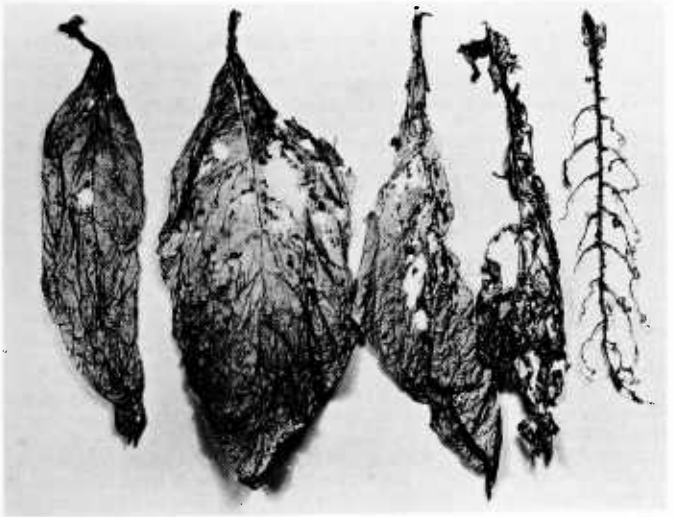

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Figure 6.—Damage to leaves of flue-cured tobacco by larvae of the tobacco moth. About one-fifth natural size.

silken thread that forms a webbing and catches pellets of excrement. Such accumulations of webbing and excrement are unsightly and objectionable to buyers and manufacturers.

Mature larvae move out of the tobacco, or at least to the surface—a necessary migration, because the soft, fragile adult moth could not cut its way out of confinement. It is often trapped while trying to crawl through very tiny openings. The moth apparently does not mate in close confinement; therefore, it must emerge before fertile eggs can be laid.

The tobacco moth feeds on many stored products besides tobacco. In the United States it has been found in almost all grains, as well as in peas, beans, cornmeal, wheat flour, rolled oats, peanut meal, poultry laying mash, stock feed, and various cereal products. It has also been reported as infesting cacao beans, shelled nuts, linseed meal, coffee, chicory, ship's biscuits, cottonseed cake, cayenne pepper, rice, pearl barley, other seeds, peanuts, and dried citrus pulp (7).

OTHER PESTS OF TOBACCO

Several insects other than the cigarette beetle and the tobacco moth also feed on tobacco and may occasionally cause some injury.

The larger tobacco beetle (*Catorama tabaci* Guer.) is primarily a tropical species, but it has been reported in Florida and Puerto Rico. It attacks cured tobacco in much the same way as does the cigarette beetle. It resembles the cigarette beetle, but is larger and is black instead of brown.

The phycitid moth *Tlascala finitella* (Wlkr.) was taken from flue-cured tobacco at Richmond, Va., in 1932, and a few individuals have been observed since that time.

The larva of an *Aglossa* moth, presumably *caprealis* (Hbn.), feeds on moldy or partly decayed tobacco. It is sometimes observed in warehouses and farmers' packhouses.

The following species are listed in approximately the order of their prevalence:

Tribolium confusum Duv.
Tribolium castaneum (Hbst.)
Henoticus serratus (Gyll.)
Ahasversus advena (Waltl.)
Typhaea stercorea (L.)
Anthrenus verbasci (L.)
Lepisma saccharina L.
Ptinus hirtellus Sturm.
Attagenus piceus (Oliv.)
Trogoderma ornatum (Say)
Oryzaephilus surinamensis (L.)
Mezium americanum Lap.
Dinoderus brevis Horn
Stegobium paniceum (L.)
Sitophilus oryzae (L.)
Dermestes maculatus Deg.
Tenebrio obscurus F.
Tenebrio molitor L.
Anthicus cervinus Laf.
Anthicus floralis (L.)

Many of these insects act as scavengers, eating dead bodies of the cigarette beetle and the tobacco moth; others probably use the tobacco as a temporary shelter.

Since 1958 increasing numbers of a small black beetle, very similar in size and appearance to the cigarette beetle, have been captured in tobacco warehouses. This insect has been identified as *Catorama confusum* Fall. Repeated attempts to rear this insect on tobacco have failed, but, because it is commonly found in tobacco storages, it warrants continued surveillance.

SOURCE OF INSECT INFESTATIONS IN TOBACCO

Cigarette Tobaccos in Farmers' Packhouses

The tobacco moth is sometimes a serious pest of flue-cured tobacco on the farm. Infestation may begin even in the curing barn and continue until the tobacco is marketed. Most damage occurs in the packhouse, where the tobacco is bulked before grading. Infestation may develop from moths flying from commercial storages or farms nearby, or it may be already established on the farm and carried over from year to year in scrap tobacco, peas or beans, stock feeds, or other host foods (*15*).

Cigarette Tobaccos in Storage Warehouses

The redrying of flue-cured leaf tobacco before it is packed in hogsheads for storage destroys all stages of the cigarette beetle and the tobacco moth. Hence, leaf tobacco is free of insect infestation when it is prized into hogsheads. However, domestic cigarette manufacturers have been storing much tobacco as "strips" (the lamina of the leaf, from which the midrib has been removed). Strips are redried much more rapidly than leaf and at lower temperatures, and this process does not always destroy all insect life. It is about 98 to 99 percent effective; a few larvae or pupae may survive. Moreover, in the United States the crop of bright tobacco is redried from July through December, most of it in late summer. At this season of the year, insects are active, and almost all redrying plants and warehouses, as well as many trucks and railway freight cars in which tobacco is shipped, are infested.

If newly packed tobacco is held for even a few hours in an infested building or vehicle, it may become infested. Moths or beetles fly about and lay eggs on the tobacco or in the cracks of the hogshead or case. The larvae that hatch from these eggs immediately begin feeding on the tobacco. Tobacco packed in July or August can develop one generation of insects, and under certain conditions two generations, before cold weather begins. Tobacco for export, packed from July through September and held for even a few days in an infested storage, is almost certain to develop an infestation. Therefore, tobacco should be fumigated before shipment. In its early stages an insect infestation is not easily detected, and new-crop tobacco exported late in the summer may be infested on arrival abroad.

Turkish tobaccos are usually infested before they are imported. The tobacco moth and the cigarette beetle are common pests in Turkey, Greece, and the Balkans, and little effort at insect control is made in those countries. Moreover, many ships' holds are infested by these insects. Much imported tobacco is fumigated at the port of entry.

Warehouses that have been in use for several years may harbor an infestation even though all old tobacco is moved out before a new crop is received. Tobacco dust and scrap accumulate in cracks and crevices and under dunnage and false flooring. The tobacco moth's habit of leaving tobacco in order to pupate may also help to spread infestations.

Cigar Tobaccos

Cigar tobaccos are attacked by the cigarette beetle only. This insect is prevalent in almost every area where these tobaccos are stored. The

beetle is present in many warehouses and attacks the tobacco soon after it enters storage. During the aging or sweating process some infestation is usually present. Much imported cigar tobacco is already infested when received. Much tobacco is imported from Cuba and Puerto Rico, where the cigarette beetle is prevalent.

Manufactured Tobacco Products

Practically all manufactured tobacco products are attacked by the cigarette beetle. The beetle is a strong flier and has been known to fly 2 miles or more. In any manufacturing center beetles can and probably will fly through any open door or window. They frequently lay eggs on packaged cigars, cigarettes, or other tobacco products in wholesale or retail establishments, as well as in manufacturing plants. A package covered with paper, cardboard, foil, or cellophane and effectively sealed is protected from cigarette beetle attack. Unfortunately, however, few packages in commercial use today are adequately sealed. Eggs laid on a package hatch into tiny larvae, which often crawl around and through the folds of the wrapping, or penetrate almost microscopic holes or cracks in the package to reach and infest the contents.

Cigars are often held in open trays or boxes for 4 or 5 weeks for aging—an excellent opportunity for infestation.

In cigarette factories, leaf tobacco before manufacture is passed through a thermal vacuum process, which destroys all stages of the cigarette beetle and the tobacco moth. However, much of the tobacco brought into a factory is infested, and this tobacco may remain in the plant for several hours, or even days, before being processed. Beetles emerge from this tobacco and readily fly about in the plant. In the factory the shredded tobacco is treated with flavoring and allowed to stand for several days for the flavoring to permeate the tobacco. Eggs laid on the tobacco at this time usually do not hatch until the tobacco has been made into cigarettes and packaged.

At a moderate temperature and high relative humidity the cigarette beetle is active and breeds the year round. It thrives best at about 80° F. and 70 percent relative humidity. Great care should be taken to eliminate any accumulations of scrap tobacco and not to retain more than a few days' supply of tobacco in the processing area of the factory.

CONTROL ON THE FARM

Sanitation

Once an infestation of the tobacco moth has developed in a farm packhouse, the farmer's simplest course is to grade and market the tobacco as quickly as possible. However, he can do a lot to prevent an infestation. As soon as a crop is graded and sold, the packhouse and grading room should be thoroughly cleaned, even the walls brushed down. All scrap tobacco should be hauled away and scattered thinly over the fields or destroyed. No seed, feed, or fertilizer should be stored in the packhouse. In the spring when the moths emerge, they will fly away in search of material in which to lay their eggs. The young larvae from such eggs as may be laid in a clean packhouse will die for lack of food. If grain or feed is stored in the packhouse, the moth will breed in this material until the tobacco is harvested.

Residual Sprays

A thorough application of 5-percent DDT spray to the walls and ceilings of the packhouse early in the spring (during March in South Carolina or eastern North Carolina and during April in central North Carolina and Virginia) can be beneficial. The most desirable formulation is DDT wettable powder in water. It should be applied as a coarse, wet spray, and surfaces should be wet almost to the runoff stage. The DDT residue will kill the moths that rest on a sprayed surface for a sufficient time. It will continue to be effective for a month or more (*15*).

Space Treatments or Mists

If an infestation develops and it is necessary to hold the tobacco for more than 2 or 3 weeks, it may be desirable to treat the airspace inside the packhouse with pyrethrum in oil once or twice a week. This mist spray should contain 0.2 percent pyrethrins, with or without a synergist, in a light volatile oil. Specifications for a suitable oil are as follows (*10*).

Specific gravity at 60° F	0.77–0.80.
Flash point (Tag closed cup)	140° F. minimum. 160–170° F. preferable.
Initial boiling point	370° F. minimum.
Distillation end point	490° F. maximum.
Unsulfonated residue	97% minimum.
Color	Water white.
Odor	Neutral—no kerosene or naphtha odor, no residual odor.

Such a formulation can be bought already mixed, or the farmer can easily mix it himself (*14*).

This treatment creates only a slight fire hazard when prepared as directed. It is relatively harmless to man. **No open flames, such as oil lanterns or lamps, and no smoking should be permitted in the packhouse while the treatment is being applied.** The mist should be directed so as to fill the airspace. Thorough treatment is important.

CONTROL IN STORAGE WAREHOUSES

Insect Traps.—To provide an index of infestation and a guide for timing control measures, suction/light insect traps (described below) should be installed in all storage warehouses and operated continuously from early in spring until late in fall.

Such a trap consists of a barrel, a flange of sheet metal, and a cone of 20-mesh bronze, brass, or stainless-steel screen wire. To the small end of the cone is soldered the rim of a fruit jar lid, and into this lid is screwed a glass jar of suitable size. A 40- to 50-watt light is suspended from the front of the flange. A fan operated by a small electric motor in the barrel of the trap provides suction. The motor is usually of $\frac{1}{20}$ horsepower or less, so that the fan and light combined consume less than 1 kilowatt of electricity in 24 hours.

Since the cigarette beetle is attracted to light, a suction/light insect trap aids in reducing populations of this insect. The tobacco moth is only slightly attracted to light, but any insect flying near the mouth of the trap is caught by the suction. Consequently, although a trap may not significantly reduce the population of tobacco

moths, it does catch a sufficient number to indicate the beginning, peaks, and end of seasonal variations in numbers of the insect.

A trap, preferably mounted on a cord and pulley so that it can be readily lowered for examination, should be suspended from the ceiling of the warehouse above the top of the hogsheads or bales of tobacco. In small storage units, one trap per unit should be used. For use merely as a measuring device to record the relative insect population, one trap per one-story warehouse is satisfactory in storages up to 500,000 cubic feet.

All traps should be operated 24 hours a day. Operation for only part of the day will not give an adequate sample.

Traps should be cleaned thoroughly and the motors oiled every 3 months. The wire gauze cone should be brushed off at least once a month, otherwise the meshes will become clogged with dust and the suction will be reduced.

STORAGE PROCEDURE.—Flue-cured tobacco is highly attractive to the cigarette beetle, but burley and Maryland tobaccos are rarely, if ever, damaged. For this reason the burley tobaccos, which would not need to be fumigated, should be segregated. It is not economical to mix hogsheads of flue-cured and burley tobaccos throughout a number of warehouses so that all will require treatment.

The cigarette beetle is particularly attracted to "stems" of flue-cured tobacco (midribs that have been stripped from the lamina of the leaf). It seems to prefer to lay its eggs in the crease or fold of these stems. The stems are so coarse and rigid that they cannot be tightly compacted; hence, the beetles can readily crawl through and

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Figure 7.—Interior of a storage warehouse containing hogsheads of flue-cured tobacco. Note screened door and suction/light insect trap.

penetrate the entire mass. Stems are nearly always heavily infested by the cigarette beetle, and a few hogsheads can serve as a dangerous focus of beetle infestation. Stems should never be stored in a warehouse with other susceptible tobacco.

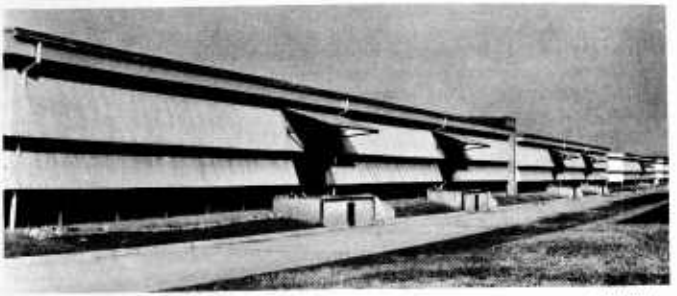
For many years all cigarette manufacturers have customarily stored 3 crop-years of tobacco in each warehouse. For economic reasons it is impractical to segregate the stocks by crop years. About ⅓ of the contents of each warehouse is used and replaced each year. As a result of this practice, warehouses are never emptied of tobacco, and "clean" tobacco is always stored in infested buildings where it is immediately exposed to infestation.

Screening.—During the summer, adults of both the cigarette beetle and the tobacco moth are constantly flying about. Therefore, all warehouses should be screened, particularly open warehouses where mists are used (fig. 7). In an unscreened warehouse, insects may readily fly out of the building ahead of the spray, only to return within a few minutes after the spraying is done. Furthermore, even should all beetles and moths in a storage be killed, the building will probably become reinfested in a few hours. Observations have been made in screened warehouses where one building was very heavily infested and an adjoining building remained very lightly infested all summer. Such differences would rarely, if ever, appear in unscreened storages.

Over a period of years it has been shown that mists give significantly better control of the tobacco moth in screened than in unscreened warehouses. Galvanized-wire screen may be used, but usually will rust out in 3 to 5 years. A more durable wire, such as copper, bronze, aluminum, or plastic, will probably prove more economical in the long run. The size of mesh used is important. To exclude the cigarette beetle, the openings in the wire should not exceed 0.0396 inch. A 20-mesh wire (20 strands to the inch) is preferable, but an 18-mesh wire is satisfactory if the wire strands are at least 0.02 inch in diameter (*19*).

Open-Type Warehouses

An open-type warehouse is merely a shed with open or partly open sides. It consists of a roof and a wooden framework with the sides partly covered by sheet metal, usually with louvers (fig. 8). The floor



BN-16191

Figure 8.—Open-type tobacco warehouses with louvered sides.

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may be of cinders, crushed rock, concrete, or wood. Storages of this type vary in size, but most of them exceed 100 by 150 feet by 16 to 18 feet high. The capacity of a single section may range from 800 to more than 3,000 hogsheads. Few of the more modern warehouses have a capacity of less than 1,500 hogsheads.

Almost half of the cigarette tobacco stored in the United States—most of the flue-cured tobacco held for domestic manufacture—is stored in open-type or semiclosed warehouses. This tobacco is attacked by both the cigarette beetle and the tobacco moth, and in such buildings insect control is a difficult problem. Fumigation is impossible or impractical and aerosols or vapor-phase insecticides are almost useless in open sheds.

An insecticide for use in tobacco warehouses must meet several requirements. Besides being an effective insecticide, the material should be volatile, leave no objectionable odor, leave no harmful or objectionable residues, impose no serious fire or explosion hazards, and be easy and safe to apply. Water sprays are not advisable because they may increase the moisture content of the tobacco and cause the development of molds and rots.

Pyrethrum in oil fits these specifications. Pyrethrum is a good contact insecticide and one of the least hazardous to man. The mist is highly volatile, losing its effectiveness in a few hours. It leaves no permanent odor or objectionable residue when correctly applied. Care should be exercised in its use. Repeated wetting of hogsheads or bales of tobacco with the liquid insecticide may taint the tobacco. Concentrated accumulation of pyrethrum mists on large sprinkler-system pipes full of water can cause moisture to drip on hogsheads directly below and has been known to taint tobacco (*14*). The oil recommended for use as a diluent for pyrethrum for treatment of tobacco warehouses is of a light volatile type. The specifications for such an oil are given on page 15. Pyrethrum-oil mists kill insects that they hit directly. They do not penetrate the hogsheads or bales of tobacco and cannot reach the insects in the tobacco.

Treatment should be started when the weekly trap catch reaches 10 tobacco moths or 10 cigarette beetles. It should be continued until insect activity is slowed by low fall temperatures. The object of the space treatment is to kill the adult insects before they have laid many eggs. Applications should be made weekly or more often, preferably on the same days each week, and care should be taken to see that all parts of the warehouse are reached.

To control the tobacco moth, the mist should contain 0.2 percent of pyrethrins. The cigarette beetle is more resistant to insecticides, and for use against this insect the formulation should contain 1 percent of pyrethrins. The dosage rate should be about 3 fluid ounces of the pyrethrum-oil mixture per 1,000 cubic feet of airspace. (The airspace of a warehouse is the volume of the building less the volume of space occupied by tobacco.) Formulations of pyrethrins with a synergist added are available for use as space treatments if desired. Follow the manufacturers' recommendations if these are used.

Flight activity of the cigarette beetle is largely restricted to late afternoon and early night. During the working day (7 a.m. to 5 p.m.), less than 10 percent of flight activity occurs. Flight activity of the tobacco moth is more uniform throughout the 24 hours, but this insect also is slightly more active during the afternoon and early

BN—4595

Figure 9.—Applying pyrethrum-oil mist in a tobacco warehouse containing flue-cured tobacco.

evening. Because more insects are active in the airspace of a warehouse from 4 p.m. to midnight, it is important that mist applications be made at that time. Evening applications consistently have given better results (*12* and *14*).

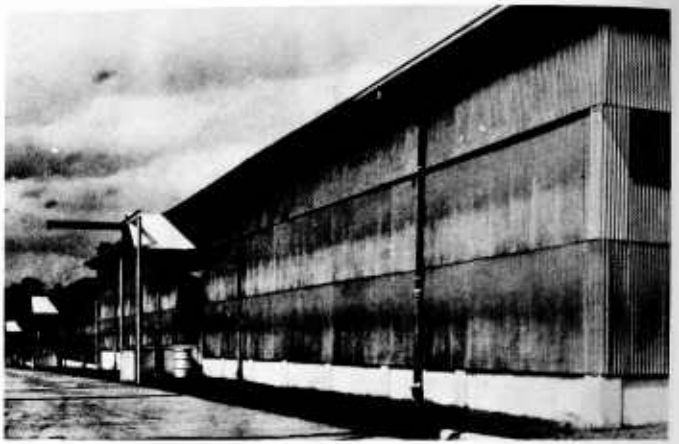
A mist blower has been especially designed for operation inside open-type tobacco warehouses. This blower will deliver about 2,400 cubic feet of air per minute at an initial velocity of about 5,700 feet per minute. Such a machine will blow a mist 100 feet or more, and reasonably good coverage can be obtained in open warehouses, even with a breeze of 6 to 7 miles an hour (fig. 9).

Fire-insurance underwriters have approved the use of pyrethrum-oil space treatments in tobacco warehouses when prepared and used as directed. Although the flash point of the oil generally used in these sprays is approximately 175° F., such oil is moderately flammable and might be explosive under certain conditions. When the equipment is to be taken into a building, only electric machines should be used. Sparkproof motors and switches and heavy-duty rubber-jacketed extension cord containing a grounding wire should be used on the blowers.

All precautions recommended by the interested fire insurance companies should be carefully followed (*14*).

Semiclosed Warehouses

Since World War II some of the larger cigarette manufacturers have eliminated the louvers and closed the sides of their open-type



BN—16198

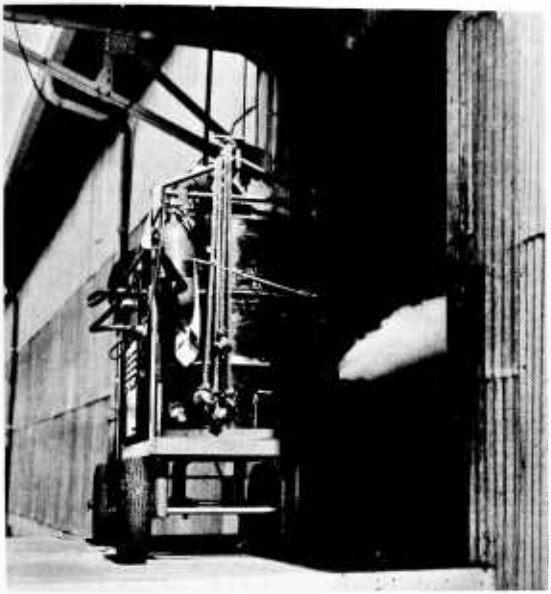
Figure 10.—Semiclosed type of tobacco warehouse. Note corrugated metal siding and absence of windows and ventilators.

warehouses. These semiclosed warehouses are rather loosely constructed of corrugated iron, usually with concrete floors. They may be of one- or two-story construction, with or without ventilators and windows, and with doors on opposite sides of the ground floor. However, as a rule, the doors on one side are never used. Such buildings have numerous cracks at the joints of the corrugated metal siding, but they have no cross ventilation. They cannot be sealed for fumigation, but they can be efficiently treated with aerosols, mists, or vapor-phase insecticides. A typical example of such a warehouse is shown in figure 10.

AEROSOLS AND MISTS

Pyrethrum-oil aerosols can be used to advantage in semiclosed warehouses. The same formulations, concentrations, and dosages are recommended as for mists in open-type warehouses. The advantage of an aerosol over a mist is that the finer particles permit better distribution of the insecticide. However, the finer droplets of an aerosol may remain suspended in the air for 1 or 2 hours, and it is essential that all doors and ventilators be kept closed during this period. Distribution or coverage is essential, because the insects in the airspace must be hit with the insecticide.

When a thermal aerosol is used, adequate distribution of the particles often is not obtained. Because of the fire hazard, fire insurance underwriters have banned taking an aerosol generator into tobacco warehouses. The machine is usually stationed at a door and the aerosol is blown through the door and into the central aisle (fig. 11). An aerosol so introduced may not be well distributed because of the large size of the building, the racking of the hogsheads, and the low headspace above the hogsheads. If the hogsheads are racked four tiers high with dunnage between the tiers, they form an almost perpendicular wall more than 16 feet high on each side of the aisle. If there



BN–18199

Figure 11.—Introducing a thermal aerosol into a semiclosed tobacco warehouse.

is only 2 or 3 feet of headspace between the top of the hogsheads and the ceiling, the aerosol may not penetrate to the back areas of the building in sufficient quantity to be effective. If the headspace is partly blocked by large beams or by sprinkler pipes, distribution of the aerosol is further restricted. Numerous tests have demonstrated that under such adverse conditions, adequate quantities of aerosol do not reach the rear areas of the storage.

In using aerosols, a concentration of 0.2 percent of pyrethrins for the tobacco moth or 1 percent of pyrethrins for the cigarette beetle is needed, the same as in using the mist. A dosage-rate of 3 fluid ounces of insecticide per 1,000 cubic feet of airspace is essential to give adequate distribution in large warehouses. However, in small warehouses of 15,000 square feet or less of floor space (such as are sometimes used for Turkish or cigar tobaccos), with a clear head-space of 5 or 6 feet or more, and with numerous open aisles between the bales, a lower dosage is satisfactory. In such buildings good results have been obtained with 2 to 2½ ounces per 1,000 cubic feet of airspace.

The recommendations for the use of mists in open-type warehouses are also applicable in semiclosed warehouses.

VAPOR-PHASE INSECTICIDES

DDVP (2,2-dichlorovinyl dimethyl phosphate) can be used advantageously in semiclosed warhouses. This is a vapor-phase insecticide, which kills by means of a vapor that is released from the

deposit when used as an aerosol; kill is increased by contact of DDVP particles with the insect. At the recommended dosages, DDVP will not affect the flavor or aroma of tobacco. This phosphate insecticide is somewhat dangerous to handle and apply but has certain advantages over contact materials that are effective only for the short time the particles are in the air.

DDVP may be applied as an aerosol at a dosage rate of 1 to 2 grams actual DDVP per 1,000 cubic feet once or twice a week. One gram per 1,000 cubic feet once a week will give good control of the tobacco moth. It is desirable to apply 2 grams per 1,000 cubic feet twice a week for the cigarette beetle (*17* and *18*). At a dosage rate of 2 grams per 1,000 cubic feet, the vapor will have a continuous killing action for 3 to 4 days. However, any appreciable ventilation will dissipate the vapor so that a lethal concentration cannot be maintained. The killing action of DDVP vapor is relatively slow, and the vapor concentration decreases each day following treatment. Nevertheless, although beetles may survive many hours' exposure, few eggs are laid while the beetles are continuously exposed to the vapor.

Liquid DDVP is highly dangerous. Every precaution should be taken to avoid getting it on the skin or clothing. It can be absorbed readily through the skin, and if accidentally spilled on the body it should be quickly washed off with liberal use of soap and water. If the liquid is spilled on shoes or clothing, they should be removed immediately and not worn again for several weeks or until washed or dry cleaned. It is highly dangerous to breathe DDVP aerosol (*4* and *17*). However, there is no danger to laborers working continuously 8 hours a day in warehouses treated at the dosages recommended **provided they do not enter the building either (a) for 4 hours after application of DDVP or (b) before the building has been ventilated.** It is preferable to apply DDVP in the evening after working hours. The next morning, work may be carried on as usual in the treated storages.

DDVP also may be applied by sprinkling it upon a **wooden surface. It should not be applied on concrete** as there is a chemical reaction that reduces the effectiveness of the insecticide. However, it can be applied on boards laid on a concrete floor. This method of application has certain advantages over an aerosol. It is cheaper, since expensive equipment is not required and solvent for further dilution is not needed, and it is effective over a longer period. The emulsifiable concentrate (4 pounds per gallon) may be used. Because of the danger involved in handling DDVP, this insecticide should be applied by qualified pest control operators, who should wear gas masks during the application. **It should never be trusted to unsupervised, unskilled laborers.**

Both contact insecticides and vapor-phase insecticides have definite limitations. Such materials can reach and kill only those insects in the airspace. Since they do not penetrate hogsheads, cases, or bales, they cannot reach those insects buried in the tobacco; consequently, they are no substitute for fumigation, which does penetrate. However, they can be used where fumigation is impractical. Both pyrethrum and DDVP are highly effective against the tobacco moth, but much less effective against the cigarette beetle. The cigarette beetle can and does breed within the mass of the tobacco, and in a well-

established infestation many beetles never emerge from the tobacco to where they can be reached by pyrethrum or DDVP.

Closed-Type Warehouses

The closed-type warehouse differs from the open-type and the semi-closed type in that it can be sealed for fumigation. In closed warehouses winter temperatures do not drop so low, and the cigarette beetle is often a more important pest than the tobacco moth. Warehouses of this type may be one story or several stories, but all have doors, windows, and/or ventilators (figs. 12 and 13). The buildings vary greatly in size—from 25,000 to more than 1 million cubic feet. Many closed warehouses consist of long rows of sections separated by brick fire walls. Some of them contain more than 100 million pounds

BN—16195

Figure 12.—An old, closed-type tobacco warehouse. Note brick construction and numerous windows.

BN—16200

Figure 13.—A large group of closed-type tobacco warehouses.

BN-6258

Figure 14.—A metal-clad, closed-type tobacco warehouse, especially designed to make fumigation easier. Note ventilators on side; others are on roof.

of tobacco. The cost of labor in moving such large quantities of tobacco to fumigation chambers makes chamber fumigation impractical. The only feasible method of insect control, therefore, is to fumigate each warehouse.

One type of closed warehouse, the idea for which was developed by the Stored-Tobacco Insects Laboratory, of the Market Quality Research Division, has been widely adopted. The walls are of flat "V-crimped" sheet metal over a wooden frame. The joints of the metal are locked and sealed with a calking compound. Ventilators and doors close against gaskets, so that the storage can be quickly and easily sealed for fumigation. Such a building is shown in figure 14. A similar, but more substantial, warehouse can be constructed of cinder block, cement block, or brick.

MISTS, AEROSOLS, AND VAPOR-PHASE INSECTICIDES

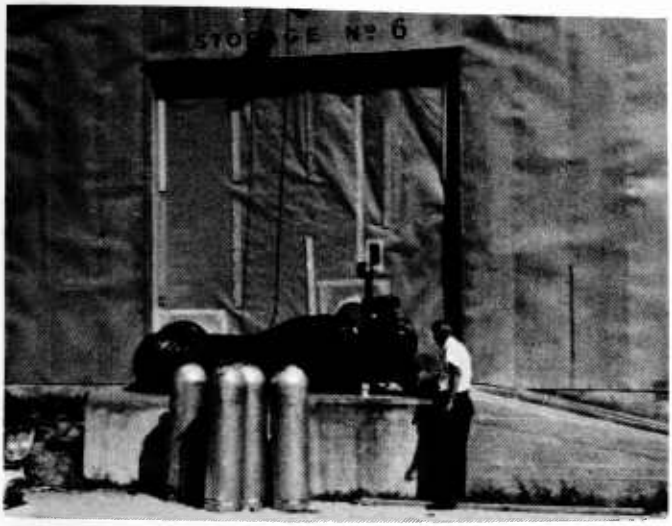
Pyrethrum-oil mists or aerosols and DDVP are more effective in closed-type warehouses than in open-type or semiclosed storages. The systematic use of DDVP or of pyrethrum can almost completely eliminate an infestation of the tobacco moth. Weekly applications of DDVP have proven more efficient and much cheaper than fumigation in controlling this insect. DDVP or pyrethrum treatments may also aid in holding down a cigarette beetle infestation, and may decrease the number of fumigations necessary. In light beetle infestations, such treatments may give satisfactory control, but in heavy infestations they will not. Against a heavy, well-established beetle infestation, there is no substitute for fumigation.

The recommendations for use of DDVP or of pyrethrum treatments in semiclosed warehouses also apply to closed-type warehouses.

WAREHOUSE FUMIGATION

For effective control of insects by warehouse fumigation, the building must be adequately sealed. All openings in the walls, floors, and ceiling, such as windows, doors, ventilators, eaves, skylights, and elevator shafts, must be closed and the building made gastight.

One method of sealing warehouses, which has been used for many years, uses a heavy gastight paper (such as sisal kraft), paste, asphalt, elastic roofing cement, calking compound, and paper masking tape. Large openings are closed with heavy paper sealed with paperhangers' paste or masking tape (fig. 15). The eaves are sealed with tarred



BN–16201

Figure 15.—Door of a tobacco warehouse partly sealed for fumigation. Sisal kraft paper has been tacked and pasted over screen door.

paper and asphalt. Polyethylene sheeting of 4-mil thickness may be substituted for heavy paper. Cracks are filled with a mixture of four parts asbestos fiber to one part of calcium chloride and enough water to make a stiff dough. For small cracks calking compound or elastic roofing cement is excellent (fig. 16).

Since the late 1940's or early 1950's, many warehouses have been sealed by spraying a vinylite plastic over cracks and around doors, windows, and ventilators. The plastic is applied with a paint spray gun powered by compressed air. When properly done this sealing is semipermanent. It requires less labor than other common methods of sealing, but a greater capital investment is needed for an air compressor, airhose, spray guns, and a motortruck (fig. 17). Companies that have many warehouses can afford such equipment, but the cost is too high for small companies. Sealing with plastic has one great advantage—it can be done very rapidly. Sometimes the need for fumigation develops quickly, and speed in preparing the building is important. Sealing a warehouse with vinylite plastic is shown in figure 18.

The basis of the vinylite plastic used for sealing tobacco warehouses is a plasticized vinyl chloride-acetate copolymer resin. It is prepared for spraying by adding solvents such as methyl ethyl ketone and acetone. After the solvents have evaporated from the sprayed material (a matter of only a few minutes) a tough flexible film is left, which is quite durable. Pigments may be added to the liquid material as it is prepared for spraying, or the plastic may be purchased with a pigment included in the formulation. One of the best pigments found is finely powdered aluminum. Such a pigmented film is more resistant to sunlight and to weathering, and coatings applied to the ex-

BN—16192

Figure 16.—Eaves of a tobacco warehouse sealed on the inside with elastic roofing cement.

BN—16282—A

Figure 17.—Equipment used in sealing tobacco warehouses with sprayed-on vinylite plastic.

terior of tobacco warehouses over an adhesive base have been known to last for more than 10 years. The only maintenance necessary has been occasional touching up of spots that have been accidentally torn or broken by equipment or laborers.

This plastic also can be applied without an adhesive to give a strippable film for temporary sealing of doors, windows, or ventilators that must be reopened after fumigation.

Application of vinylite plastic should not be made to greasy surfaces or to asphalt and should not be attempted on exteriors in rainy weather. The film will not adhere well to a wet surface (*8*).

BN–16202

Figure 18.—Sealing around window of a tobacco warehouse with sprayed-on vinylite plastic.

In one method of fumigation, the warehouse should be piped with ⅜-inch copper or plastic tubing. Small brass spray nozzles should be so located as to provide the proper distribution of gas—one nozzle for each 15,000 to 25,000 cubic feet. The piping system should be so arranged that the gas pressure is about the same at all nozzles. Large warehouses that have several floors require branch lines with separate risers. From 10 to 18 nozzles may be used to a riser. Detailed plans

for piping warehouses can usually be obtained from any fumigation company after a survey of the building.

Hydrogen cyanide fumigation also can be performed with portable rubber hose lines. These lines, with nozzles about every 25 feet, are laid on the floor of the central aisle. Usually two or more lines that extend the length of the aisle are used.

In 1959–60, a new method was developed, which introduces fumigants into a tobacco warehouse by a blower fumigant applicator. The liquid fumigant is introduced through an opening in a sealed door by a high-velocity blast of air. A flexible duct connecting the warehouse to the intake of the blower permits recirculation of air. This method results in a more rapid volatilization of the fumigant, higher gas concentrations, and a more uniform distribution of the gas during the first hours of the fumigation than the older methods. Uniform distribution of high gas concentrations during the initial period produces greater penetration of the fumigant and gives better results. Such an applicator is shown in figure 19.

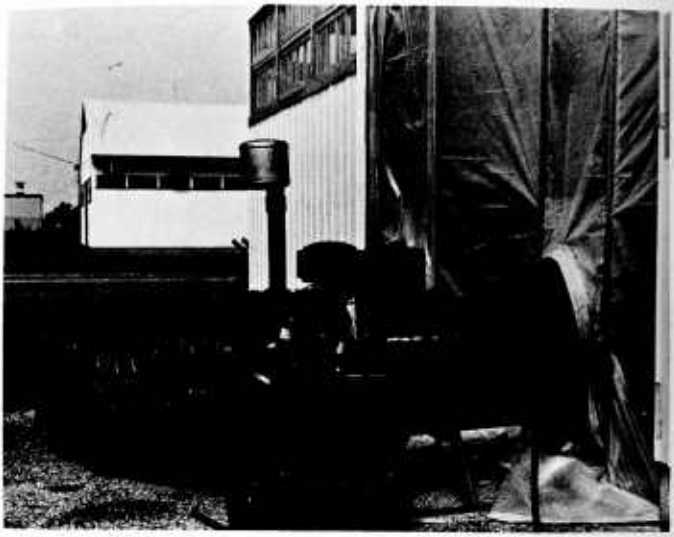


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Figure 19.—Blower fumigant applicator introducing hydrogen cyanide into a warehouse.

For many years hydrogen cyanide has been the fumigant most generally used in tobacco warehouses. Liquid hydrogen cyanide in steel pressure cylinders is used. An air compressor pumps air into the cylinder through an intake valve until a pressure of about 100 pounds per square inch is reached. The pressure forces the fumigant through the piping system or hose lines and out of the spray nozzles. When only a part of a cylinder of gas is needed, the cylinder may be weighed on portable platform scales until the required amount is used.

The operator should read the safeguards at the end of this

handbook and be certain that all persons and animals are out of the building before beginning introduction of gas. When the required dosage has been introduced into the building, the valve on the cylinder should be closed and the piping system blown clear of gas by air pressure. The inlet pipe into the warehouse should then be capped.

The dosage of hydrogen cyanide needed varies somewhat with the tightness of the warehouse. For years a dosage of 16 ounces per 1,000 cubic feet, with an exposure of 72 hours, has been considered more or less standard. However, in warehouses with floors of cinders or crushed rock, or where more than the usual leakage is anticipated, the dosage should be increased to 20 ounces. To obtain deeper penetration of the hogsheads, much heavier dosages of fumigant sometimes may be used advantageously in very tight buildings. A dosage of 48 ounces, with an exposure of 120 hours, gives much better penetration. Under nearly ideal conditions, one such heavy fumigation may be as effective as three standard fumigations. A former practice of controlling the heavy emergence of beetles by applying a series of low-dosage (8 to 12 ounces per 1,000 cubic feet) fumigations is no longer considered effective or economical.

Methyl bromide also may be used in warehouses of flue-cured tobacco. This fumigant is equally as effective as hydrogen cyanide. The standard dosage is usually 24 ounces per 1,000 cubic feet, with a 72-hour exposure. This dosage should be increased to 2 pounds per 1,000 cubic feet, if additional leakage or sorption factors are known or suspected. Methyl bromide penetrates better than hydrogen cyanide, but occasionally has been reported as tainting tobacco.

In all warehouse fumigation, the temperature of the tobacco should be 70° F. or higher. In the United States, therefore, fumigation usually is limited to the summer and early autumn.

Under favorable conditions, warehouse fumigation at the standard dosage kills all stages of the moth and beetle (eggs, larvae, pupae, and adults) to a depth of 1 to 3 inches in the tobacco and kills a few insects to a depth of 5 inches. In heavy-dosage fumigation with hydrogen cyanide, complete kills may be expected to 5 inches and heavy kills to 7 inches. Unfortunately, however, some insects deep in the tobacco usually survive.

The value of a fumigation may be destroyed by strong winds; they suck the gas out of a building very quickly.

Infested tobacco moving into a newly fumigated warehouse may quickly reinfest it and nullify the benefits of the fumigation.

The following dosages of fumigants are suggested for warehouse fumigation at 70° F. or above:

Fumigant and type of tobacco	*Dosage Lb./1,000 cu. ft.*
Hydrogen cyanide:	
Flue-cured	1 to 3
Turkish	1 to 1¼
Cigar filler or binder	1 to 1¼
Methyl bromide:	
Flue-cured	1 to 1½
Turkish	1 to 1½
Cigar filler or binder	1 to 1½
Acrylonitrile-carbon tetrachloride:	
Flue-cured	3½ to 4
Turkish	3½ to 4
Cigar filler or binder	3½ to 4

Tarpaulin Fumigation

Small lots of tobacco may be fumigated under tarpaulins. For this purpose, polyethylene sheeting of 4-mil thickness is satisfactory and readily available. Widths of the sheeting can be sealed together with masking tape. The edges can be sealed to a clean, tight, wooden or concrete floor with masking tape or by a "snake"—a long bag or tube filled with water or dry sand. Dosages of fumigants and the length of exposure should be the same as those used in warehouse fumigation.

An Insect-Control Program in Tobacco Warehouses

Suction/light insect traps should be placed in operation before the earliest spring emergence of insects. This date ranges from March 1 in eastern South Carolina to April 15 at Richmond, Va., and about May 1 in eastern Pennsylvania.

As soon as light traps in a warehouse show a weekly catch of 10 tobacco moths or cigarette beetles, insecticidal treatments should be started. In open-type warehouses, pyrethrum mists may be used. In semiclosed and closed warehouses, DDVP or pyrethrum is recommended. For the moth, weekly applications of 1 gram of DDVP per 1,000 cubic feet should be applied either as an aerosol or a mist or by sprinkling on wood; or 3 ounces of pyrethrum in oil (containing 0.2 percent pyrethrins) per 1,000 cubic feet of airspace should be applied as a mist or an aerosol. These treatments will give excellent control of the tobacco moth but are inadequate for the cigarette beetle. Therefore, as soon as the beetle appears, the dosage should be increased to 2 grams of DDVP per 1,000 cubic feet, applied twice a week as an aerosol or once a week sprinkled on wood; or to 3 ounces of pyrethrum in oil (containing 1.0 percent pyrethrins) applied as a mist or an aerosol. Such treatments will check the potential increase of a beetle population but will not control a serious infestation.

When a weekly trap catch of beetles exceeds 2,000 per week in warehouses of flue-cured tobacco, need for fumigation is indicated. In warehouses of cigar tobacco—especially cigar wrapper tobacco—fumigation may be justified by a much lighter infestation.

The question of when and where to fumigate is sometimes difficult to answer. The problem may be complicated by the type, age, and value of the tobacco, the degree of infestation, and previous treatment. As a rule it is advisable to fumigate a warehouse as soon as practical after the peak of adult emergence of an insect brood or generation. However, in very heavy infestations, it is sometimes impractical to wait that long. Immediately after a peak of brood emergence, a larger percentage of the insects are in the egg or early larval stage and are nearer the surface of the tobacco. At this time they are more exposed and more susceptible to the fumigant.

Complete kills of insects are rare in the fumigation of tobacco warehouses. For this reason it is important to keep a constant record of the insect populations present by use of suction/light traps. A knowledge of the relative insect population is indispensable as a basis for intelligent application of control measures.

CONTROL BY CHAMBER FUMIGATION

Atmospheric Chamber

Small chambers equipped for the fumigation of tobacco at atmospheric pressure are satisfactory in many tobacco plants. Most such chambers are 2,000 to 5,000 cubic feet in size, but some are larger. A chamber may be constructed of wood and tar paper, metal, concrete, or brick. It should be made tight by installing refrigerator-type doors that close against a gasket. The walls should be covered with asphalt or heavy paint. An epoxy-type paint has been found to be very satisfactory.

The chamber can be piped in the same way as warehouses. If hydrogen cyanide or methyl bromide is to be used, the inlet of the piping system should be in a small room attached to the chamber. The room need be only about 3 feet square—just large enough to hold a platform scale on which rests the cylinder of fumigant. From the top of this room should extend a vent pipe connected to an electric fan. The fan should be operated when gas is introduced into the chamber, so that any leakage is drawn up and away from the operator. The fumigation chamber should have a vent pipe, operated by readily accessible valves, extending well above the roof of the building. A powerful fan should be connected to this vent to exhaust gases from the chamber quickly, and the fan should be kept running when the fumigation chamber is entered after fumigation.

Acrylonitrile-carbon tetrachloride may be poured into shallow pans in the chamber. **The operator should wear a suitable gas mask while pouring.** A superior method is to place a large, shallow stainless-steel pan on a steam or hot-water coil near the ceiling of the chamber and run a small pipe through the wall or ceiling of the chamber so that it will discharge into the pan. The outer end of the pipe is connected with a funnel, held in a vertical position. The required dosage of fumigant is placed in a glass or stainless-steel container which is then inverted over the funnel, and the liquid fumigant flows into the pan by gravity. **However, the liquid acrylonitrile-carbon tetrachloride mixture is flammable, and care should be taken to avoid exposure to spark or flame.** At the dosages recommended the gas is not explosive, but like many other fumigants, it is both flammable and explosive at high concentrations. Unnecessary electric or telephone lines therefore should be disconnected before fumigation is begun.

Discoids impregnated with hydrogen cyanide may be used in atmospheric chambers, but they are more dangerous to handle than the liquid hydrogen cyanide. **The operator should wear a gas mask with suitable canister, and he should leave the chamber as quickly as possible after scattering the discoids. This is a dangerous operation and should not be undertaken by an inexperienced person.**

If hydrogen cyanide is used, the dosage should be at least 16 ounces per 1,000 cubic feet, and as much as 24 ounces may sometimes be used to advantage. The exposure for hogsheads of tobacco should be 72 hours. If acrylonitrile-carbon tetrachloride is used, the amount should be 32 to 48 ounces per 1,000 cubic feet, with an exposure of 72 hours for flue-cured tobacco in hogsheads. For bales of Turkish tobacco and for bales or cases of cigar filler or binder tobacco, 32 ounces per 1,000 cubic feet, with an exposure of 48 hours, has proved

satisfactory. All dosages given are to be used at a tobacco temperature not lower than 70° F.

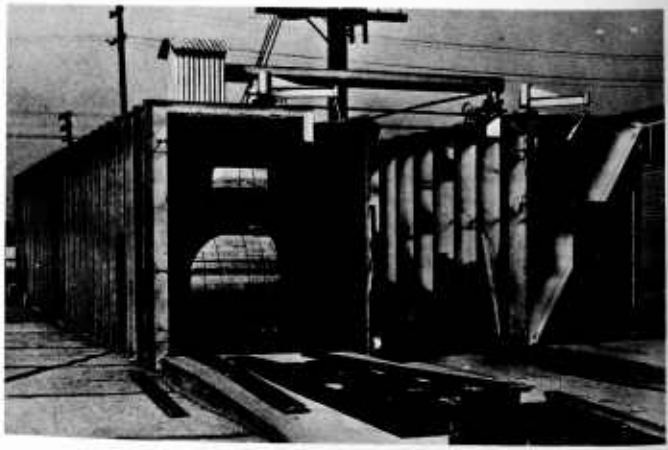
In the fumigation of tobacco in atmospheric chambers, bales and cases should be stacked with slats between them and with airspaces on all sides to facilitate penetration of the gas into the tobacco. In all atmospheric chambers an explosionproof and sparkproof electric fan should be operated for 1 to 4 hours at the start of each fumigation to help distribute the fumigant and prevent possible stratification of the gas. Better penetration is usually obtained in atmospheric-chamber fumigation than in warehouse fumigation. However, fumigation is not so effective in atmospheric chambers as in vacuum chambers.

The following dosages of fumigants are suggested for atmospheric chambers at 70° F. or above:

Fumigant and type of tobacco	*Dosage Lb./1,000 cu. ft.*
Hydrogen cyanide:	
Flue-cured, Turkish, cigar filler or binder	1
Methyl bromide:	
Flue-cured, Turkish, cigar filler or binder	1 to 1½
Acrylonitrile-carbon tetrachloride:	
Flue-cured, Turkish, cigar filler or binder	3½ to 5

Vacuum Chamber

The fumigation of tobacco in a partial vacuum is the most effective method known for destroying insect infestations. When properly performed, it should kill all stages of the cigarette beetle and the tobacco moth at all depths in the tobacco. Vacuum chambers are expensive, but they are extensively used because of their efficiency and the rapidity with which they can be operated.



BN-4593

Figure 20.—Vacuum-fumigation chambers filled with hogsheads of tobacco.

EQUIPMENT AND PROCEDURE

Vacuum fumigation equipment usually consists of a pair of steel chambers strong enough to withstand considerable pressure, a pump of suitable size to evacuate the chambers, a volatilizer for the fumigant (for use in cold weather), and recording gages. The chambers vary widely in size; most of those in commercial use range from 400 to 5,000 cubic feet. In some of the larger units, each chamber has a capacity of more than 30 hogsheads (fig. 20).

The tobacco to be fumigated is placed in the vacuum chamber, the door is closed, and the air is pumped out until a vacuum of 28 to 29 inches is registered on a standard mercury gage. The degree of vacuum obtainable varies from day to day with the barometric pressure, but any vacuum of more than 28 inches is usually satisfactory. The proper dosage of fumigant is determined by weighing. The cylinder or drum of fumigant is placed on a platform scale and connected to the intake line of the chamber. When a valve is opened the gas is sucked into the chamber and drawn all through the tobacco by vacuum. The chamber is held under sustained vacuum until the end of the exposure period; then the gas is pumped out of the chamber and vented above the roof of the building. Air is then admitted to restore normal pressure in the chamber. This air is exhausted by pumping, and air is again admitted. This procedure—called air washing—is usually performed twice for each lot of tobacco. Electric fans in the vacuum chamber to facilitate distribution of the gas are desirable. The fan should be operated for about 1 hour at the start of each fumigation.

The manufacturers of vacuum-fumigation equipment can supply estimates and specifications to meet the needs of individual factories or warehouse operators.

FUMIGANTS AND DOSAGE

Several fumigants may be used in vacuum fumigation of tobacco (*13*).

Hydrogen cyanide is popular, particularly for cigarette tobaccos. It is seldom used for cigar tobaccos just before manufacture or on cigars, because the odor may persist for several weeks.

Methyl bromide has been used to a considerable extent and is an excellent fumigant, but on a few rare occasions obnoxious odors have developed in tobacco fumigated with it. Apparently the odor is due to a chemical reaction of the methyl bromide with a tobacco that is unusually high in protein nitrogen. Unfortunately, it is impractical to make a chemical analysis of each lot of tobacco before fumigation, so this reaction is unpredictable.

A 1:9 mixture of ethylene oxide and carbon dioxide has long been used for vacuum fumigation of cigars and cigar tobacco. It leaves no objectionable odor, but it is expensive and is sometimes erratic in effectiveness—especially at temperatures below 60° F.

A 34:66 mixture of acrylonitrile and carbon tetrachloride has become widely used as a tobacco fumigant. This gas is slightly less dangerous than hydrogen cyanide or methyl bromide, is relatively cheap, leaves no odor on tobacco, does not injure tobacco, and is highly effective. However, it attacks rubber gaskets and corrodes iron and steel. A 50–50 formulation of this fumigant was formerly marketed and was reported to be flammable. The present 34:66 formulation

has caused no trouble with fire and is apparently as safe in this respect as other fumigants. **All fumigants are flammable and explosive at very high concentrations.** The dosages recommended for tobacco fumigation are well within the accepted tolerances for safety. For several days after fumigation, an additional danger from all fumigants may arise from handling tobacco. Small quantities of sorbed gas are gradually released from the tobacco, which may become a hazard in confined areas.

Much tobacco is fumigated in vacuum during the fall, winter, and spring, when the temperature of tobacco is below 70° F. At such temperatures it is necessary to increase the dosage of fumigant, and sometimes the results are erratic, perhaps because the insects are less active and therefore more resistant.

Exposure of infested tobacco to vacuum alone for practical lengths of time is relatively ineffective in controlling stored-tobacco pests. Tests showed that continuous exposure to a high vacuum (above 28 inches) for 3 days killed all stages of the tobacco moth and all stages of the cigarette beetle except the egg. An exposure of 10 days was required to destroy the eggs of the beetle. However, even a 3-day exposure is impractical under most conditions.

The following dosages of fumigants are recommended for the vacuum fumigation of tobacco at a 4-hour exposure:

Fumigant and type of tobacco	Dosage at —	
	70° F. or above	35° to 69° F.
	Lb./1,000 cu. ft.	*Lb./1,000 cu. ft.*
Hydrogen cyanide:		
Flue-cured	4	5
Turkish	4	5
Cigar filler or binder	4	5
Cigar wrapper	5	----------
Ethylene oxide-carbon dioxide:		
Cigar filler or binder	60	----------
Cigar wrapper	65	----------
Cigars	45	----------
Acrylonitrile-carbon tetrachloride:		
Flue-cured	4	5
Turkish	4	5
Cigar filler or binder	4	5

CONTROL IN TOBACCO FACTORIES

Preventing Infestation

An important source of factory infestation has always been the flight of cigarette beetles from storage warehouses nearby. The various processes—stemming, blending, bulking, handling, and manufacturing—need as much light as possible. In the past, large windows permitted entrance of the beetles. Fluorescent lighting and air conditioning have eliminated this problem in some modern buildings with screened air intakes. Unfortunately, only a few factories are so equipped.

Probably the greatest source of trouble in factories is infested tobacco that is brought into the building. Because tobacco is often held

for hours or even days before it is processed, great care should be taken not to bring infested tobacco into the manufacturing plant. In cigarette manufacture the hogsheads of tobacco almost always receive a thermal-vacuum treatment to moisten and condition the tobacco so that it can be handled without breaking. This process raises the temperature of the tobacco high enough to kill all stages of the cigarette beetle and the tobacco moth. However, it is important that the hogsheads move directly into the processing chambers as they are brought in from the warehouse; otherwise there is always danger of infesting the factory. Tobaccos that do not receive the thermal-vacuum treatment should be fumigated in vacuum or atmospheric chambers before being brought into the factory. If it is necessary to bring untreated tobacco into a manufacturing plant and hold it for even a short time, it should be placed in a receiving room screened with 20-mesh wire.

In factories that are not air conditioned, all doors, windows, and ventilators should be screened with 20-mesh wire. Homeowners more than a mile from any tobacco storage or factory have complained of large invasions of cigarette beetles. Unscreened doors and windows are an open invitation to this insect.

Fan-Guarded Doors

In all tobacco factories and leaf processing plants, tobacco is constantly moving from one area to another. In many areas doors must be kept open. Electric fans may be employed to prevent beetles from flying from the receiving area or room into the manufacturing areas. A large electric fan (at least 16 inches) should be mounted above the door at such an angle as to blow downwards and into the receiving room. The cigarette beetle cannot fly through the blast of air.

Insect Traps

Although light traps are of little value as a control measure in tobacco facilities, they are a valuable aid in determining where the insects are and in what numbers. One suction/light trap should be installed in every room or area where tobacco is handled or stored. In very large rooms there should be one trap to each 10,000 square feet of floor space. These traps should be equipped with black-light fluorescent tubes of more than 30-watt capacity (fig. 21). Traps should be installed just below the ceiling and mounted on cords and pulleys for easy servicing and inspection. They should be operated continuously. A daily or weekly record should be maintained of the beetles caught in each area. Traps equipped with black light will attract a much higher percentage of female than of male beetles and will capture two or three times as many beetles as traps with a 50-watt incandescent light bulb.

If the trap catch increases suddenly in any area, search should be immediately started for the source of infestation so that it can be eliminated.

Fumigation of Manufactured Tobacco

Cigarettes leaving the factory for channels of trade are not fumigated. A package of cigarettes is so tightly sealed that effective fumigation is impractical. However, cigarettes may become infested at the factory, and sometimes they become infested while in the hands of wholesalers or retailers. When these are returned to the manu-

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Figure 21.—Black-light/suction insect trap.

facturer some of the tobacco can be cleaned and reclaimed, but infested cigarettes should be fumigated, preferably in vacuum, before they enter the factory. The cartons of cigarettes should be opened, and if possible, the wrapping on the packages should be broken before fumigation.

Cigars need protection from the time they are made until they are shipped out of the factory. This interval may be as long as 40 days or even more. If it is not possible to keep the cigars in cool storage or an insect-tight room, it is desirable to fumigate in vacuum with acrylonitrile-carbon tetrachloride or ethylene oxide-carbon dioxide before shipment. When fumigating cigars it is advantageous to fumigate before wrapping them in cellophane. Cellophaned, boxed cigars can be fumigated, but not when the boxes also have been overwrapped with cellophane.

Pipe and chewing tobaccos are rarely fumigated after manufacture. Therefore they must be protected during storage if losses are to be prevented. Adequately sealed packages are valuable in this respect. All returned goods should be fumigated before being received into the factory for cleaning and salvage.

High- and Low-Temperature Treatments

As has been stated, the redrying process for leaf tobacco should kill all stages of the tobacco moth and the cigarette beetle. This is not necessarily true for the redrying of flue-cured strips, the laminae of the leaves after the midribs have been removed. Strips are redried

at lower temperatures and for shorter periods than is leaf tobacco; consequently the treatment is not always entirely effective.

In manufacturing cigarette or pipe tobacco, the shredded, granulated, or chopped-up tobacco is heat conditioned. In all such processes observed, the temperatures have not been high enough or maintained long enough to give appreciable insect mortality.

Cold or cool storage is of great value in preventing or checking an insect infestation. Flue-cured tobacco for export is sometimes held in storage at 50° to 60° F. to prevent loss of color and excessive fermentation. It also prevents insect infestation. As the threshold of activity for the moth and the beetle is 60° to 65°, a lower temperature will check activity and arrest insect development. If held long enough at such temperatures, the insects will eventually die.

Cold storage is sometimes used as a substitute for fumigation and has certain advantages. It does not injure tobacco, and there is no danger from poison gas. At −10° F. all stages of the cigarette beetle in bales or cases of leaf tobacco are killed in 3 to 5 days—the length of time required for the cold to penetrate the tobacco (*16*).

Cool storage is also widely used in the cigar industry to prevent cigarette beetle infestation. Valuable sweated tobaccos and finished cigars are stored in rooms at 34° to 55° F. No infestation can occur at these temperatures, since the beetle is inactivated. When unprotected by tobacco or packaging, all life stages of the beetle are killed by continuous exposure to 47° to 48° for 90 days, to 40° for 33 days, to 36° for 16 days, to 25° for 7 days, or to 15° for 3 days (*11* and *16*).

Other Treatments

When DDVP or pyrethrum is used, fumigation for the tobacco moth is not needed. For the cigarette beetle, up to four fumigations a season may be required, depending upon the infestation and other control measures employed. At Richmond, Va., the most desirable times for fumigation (based upon the peak of brood emergence) usually have been June 25 to July 5, August 10 to 25, and September 15 to 30. Of course, there may be appreciable variance from this in some years, depending upon an early or late spring and an early or late fall. **In all fumigation of tobacco, the gas should be applied only by a person especially trained for the work.** An especially trained employee should be solely responsible for atmospheric chamber or vacuum fumigation. For applications of DDVP or for warehouse or factory fumigation, it is best to employ a licensed pest-control operator.

COST OF INSECT CONTROL

The cost of insect control varies from year to year with the price of labor and insecticides, the amount of tobacco fumigated at one time, and other factors. Actual cost figures are available only for cigarette tobaccos. The cost of DDVP aerosol to control the tobacco moth only was about 12 cents per hogshead per year in 1959 and 10 cents in 1960. The cost of DDVP to control the moth and the beetle ranged from 2 cents to 33 cents per hogshead in 1959 and from 12 cents to 25 cents in 1960. In 1959 the cost of warehouse fumigation ranged from 12 cents to 52 cents per hogshead and in 1960 from 12 cents to 41 cents. In one large company storing more than

500,000 hogsheads of flue-cured tobacco, the total cost for insect control was 40 cents per hogshead in 1959 and 37 cents in 1960.

Vacuum fumigation may range from $1 to more than $4 per hogshead. At Newport News and Norfolk, Va., the charge for commercial vacuum fumigation of tobacco in 1960 was $1.70 to $1.75 per hogshead. This included the cost of the fumigant, labor, use of motorized equipment, and amortization of equipment.

SAFEGUARDS IN FUMIGATION

Carelessness is responsible for most of the accidents in industrial fumigation. The following precautions should always be taken:

Employ only trained men, preferably licensed pest-control operators, in the fumigation of warehouses and factories. Operators must abstain from intoxicants while working.

Except where electric fans are to be used, disconnect all electric lines and telephone lines into the building or chamber—preferably outside the building. Use only sparkproof and explosionproof electric fans.

Keep all persons and domestic animals outside the building or chamber when it is finally closed and sealed for fumigation. Post placards in prominent places on the building or chamber, warning that it is being fumigated with poison gas.

Keep guards and night watchmen on duty to see that no person or domestic animal approaches a building under fumigation.

Wear or carry gas masks equipped with the proper canisters at all times when handling gas.

Local authorities should be notified of the intention to fumigate and any necessary permits obtained from them. These officials should be notified again when the fumigation is completed and the building has been properly ventilated.

Before fumigation, the interested fire insurance underwriters should be notified, and their approval of the procedure should be obtained.

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